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FRENCH REPUBLIC

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PATENT OF INVENTION, UTILITY CERTIFICATE
Intellectual Property Code - Book V1

PETITION FOR GRANTING 1/3

DATE OF PRESENTATION OF DOCUMENTS	07 FEB 2001
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1. NAME AND ADDRESS OF THE APPLICANT OR AGENT TO WHOM ALL CORRESPONDENCE SHOULD BE ADDRESSED

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Your references for this dossier *(optional)*	P10-1311/JB	
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2. NATURE OF APPLICATION	**Mark one of the following 4 boxes**	
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Initial patent application	No.	Date / /

3. TITLE OF INVENTION (200 characters maximum)
Measurement of adherence between a vehicle wheel and the roadway

4. DECLARATION OF PRIORITY OR REQUEST TO BENEFIT FROM THE DATE OF FILING OF A PREVIOUS FRENCH APPLICATION	Country or orginisation	
	Date / /	No.
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7. INVENTOR(S)	
The inventors are the applicants	[ ] Yes [X] No - **In this case provide a separate designation of the inventor(s)**
8. SEARCH REPORT	**Only for a patent application (including division and conversion)**
To be drawn up immediately To be drawn up later	[X] [ ]
Phased payment of fees	**Payments in two amounts, only for natural persons** [ ] Yes [ ] No
9. REDUCTION OF LEVEL OF FEES	**Only for natural persons** [ ] Requested for the first time for this invention *(attach a notice of non fee paying status)* [ ] Request subsequent to this filing *(attach a copy of the decision of allowance for this invention or indicate its reference)* :
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10. SIGNATURE OF APPLICANT OR AGENT **(Name and capacity of the signatory)** For MFPM - Agent 422-5/S.020 Jacques BAUVIR - MFPM Employee For Odele JOUVE, MFPM Employee *(signature)*	**VERIFICATION BY PREFECTURE OR INPI** *(signature)* L. GUICHET

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PATENT OF INVENTION, UTILITY CERTIFICATE
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PETITION FOR GRANTING
Continuation page No. 1b / 2

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5. APPLICANT	
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The present invention relates to the adherence of a vehicle to a roadway. It concerns more particularly the determination of adherence characteristics between a vehicle wheel equipped with an elastic tyre such as a rolling tyre and the ground, based on obtaining physical parameters in the contact area between said wheel and the rolling surface.

It has already been proposed to take permanent measurements in the tread of a tyre while a vehicle equipped with the latter is moving, in order to know in real time the stresses which develop between a tyre and the ground. Patent application DE 3937966 A1 may be consulted on this subject. Nevertheless, however interesting it may be, such information is still insufficient, since the driver, or even an automatic device such as those covered by well known designations in the automotive field such as "ABS" or "ESP", is still incapable of anticipating a deterioration in the adherence. One therefore makes do with noting a posteriori the exceeding of an adherence limit, and as rapid action as possible is taken to control the vehicle.

There exists in this respect a requirement to obtain indications "in real time" of the adherence conditions capable of affecting, in the moments which follow, the behaviour of a vehicle, notably in cases where it undergoes a substantial acceleration, due to motive or braking forces or to a change in path. The invention is aimed at supplying means and methods of achieving this in an effective manner, by procuring as realistic information as possible on the safety margin which subsists in the driving of the vehicle.

The invention provides a tyre whose tread comprises at least one measuring element whose surface is intended to come into contact with the ground at each revolution of the

tyre, said measuring element, viewed at the surface of the tread, having a central zone surrounded by an encircling zone, said central zone having a resistance to a force directed perpendicular to the surface of the tread which is less than that offered by the encircling zone, a sensor being disposed opposite said central zone, said sensor being sensitive to at least one tangential force exerted at the surface of said central zone.

The invention therefore proposes adapting a part of the tread in order to make it exceed the adherence limit in numerous rolling circumstances. If at least one appropriate measurement is carried out in said part, a knowledge of the adherence potential may be arrived at. Here, each time that it is a question of carrying out a measurement, the required sensor or sensors may be external to the tyre itself, or embedded in the wall of said tyre, as described below.

Here "measuring element" means a part of the tread of the tyre whose structure is adapted to the aim pursued by the invention, and beneath which a sensor is implanted. The adaptation consists in providing a central measurement zone surrounded by an encircling zone and having properties identical to what is used in a significant part of the tread. The properties of the central measurement zone differ in that said zone is rendered flexible compared with the encircling zone. Said rendering flexible of the central zone makes it possible to reduce the contact pressure on the ground, which permits a gliding over the ground. There is meant by "properties" an overall evaluation having a contribution stemming from the intrinsic characteristics of the material used, and in certain cases a contribution determined by the form given by the moulding of the material, it even being possible for the latter to predominate. There is meant by "significant part" a part of

the tread which is designed solely as a function of the wear properties which the designer of the tyre desired to confer on the tyre in question, in contrast to what is desired in order to perform a measurement.

In the following, there is meant by "adherence potential of one or other element" the ratio between the overall maximum tangential force which said element, considered in its totality, may undergo during its contact with the ground, at a given place, and the normal force applied to said element.

We designate as "friction potential" the ratio between the local tangential stress and the local vertical stress which are exerted at a given point onto a rubber element gliding over the ground.

"Available adherence margin" will be called the difference between the adherence potential of an element and the ratio between the overall tangential force and the overall vertical force actually applied to said element, considered in its totality, during its passage in the contact area.

Preferably, the invention relates to a tyre whose tread is of rubber.

The invention also extends to a method for detecting a characteristic of adherence between a wheel possessing a deformable tread and a rolling ground, comprising the following stages:

a) providing in the tread at least one measuring element whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a

central zone surrounded by an encircling zone, said central zone being arranged to glide over the ground with a level of stresses parallel to the surface of the ground which is substantially weaker than the level of stresses parallel to the surface of the ground beyond which the encircling zone glides over the ground;

b) arranging a sensor opposite said central zone, said sensor being sensitive to at least one parameter reflecting a tangential force exerted at the surface of said central zone;

c) producing a first signal representative of a tangential force in said contact surface of the central zone;

d) detecting a variation in said first signal which is characteristic of a loss of adherence;

e) producing an estimate of the friction potential in said contact surface of the central zone;

f) producing an estimate of the adherence potential of the tread.

The invention naturally makes it possible to estimate the "available adherence margin" by the difference between the adherence potential of the tyre and the ratio between the tangential force and the vertical force which are actually applied to the tyre. As a non-limiting illustration, it is possible to estimate the tangential force, for example in the longitudinal direction, as well as the vertical force by means of what is described in the US patent 5 913 240. But it is also possible to estimate the tangential force and the vertical force by measures all of which are conducted in the tread. Other details will be given on this subject below.

The invention is illustrated by the following figures:

- Figure 1 is a partial overall view of a tread of a tyre, showing a first embodiment of an element of the latter adapted to the measurement in its environment,
- Figure 2 is an enlargement enabling the first embodiment of the element shown in Figure 1 to be better viewed,
- Figure 3 is a radial cross-section along III-III in Figure 2,
- Figure 4 illustrates a second embodiment of an element,
- Figure 5 illustrates a third embodiment of an element,
- Figure 6 illustrates a combination of the first and third embodiments of an element,
- Figure 7 illustrates a combination of the first and second embodiments of an element,
- Figure 8 illustrates a first variant of the first embodiment of an element,
- Figure 9 illustrates a second variant of the first embodiment of an element,
- Figure 10 illustrates another aspect of the invention,
- Figure 11 illustrates another aspect again,
- Figure 12 illustrates an embodiment variant applicable to all the embodiments presented above,
- Figure 13 illustrates another embodiment variant applicable to all the embodiments presented above,
- Figure 14 illustrates another possibility of an embodiment variant applicable to all the embodiments presented above,
- Figure 15 illustrates a possible variation, applicable to the embodiments including the first embodiment,
- Figure 16 illustrates another variation again, applicable to the embodiments including the first embodiment.

There is seen in Figure 1 a tyre exhibiting a pattern on its tread. The pattern is chosen solely as an example and

is not limiting. Said pattern comprises a certain number of rubber tread blocks 2, of sensible and variable shape, according to the rules of the art on designing treads. Here, a block of rubber limited over its entire periphery by a fairly deep recess is called a rubber "tread block". A certain number of said loaves are adapted here in order to make measuring elements 1 of them.

On each measuring element 1 (see also Figures 2 and 3) is seen a central zone 10 surrounded by an encircling zone 11. In Figure 3 is seen a sensor 12 arranged in the interior of said central zone. Such a sensor is disposed preferably radially in the interior of the part of the thickness of the tread intended to become worn ("radially" is used according to the conventional meaning in the tyre field). Said sensors are able to measure stresses or displacements. It is a matter of measuring a state or states related to the deformations or stresses which the tyre undergoes during the rolling, at the contact surface opposite said place, in the longitudinal and transverse directions. Use is made, for example, of a device with Hall effect, comprising a magnetic element 120 and at least one device with Hall effect 121.

In Figures 1 to 3 is seen a thin strip 13, that is to say a cutout of small thickness compared with the size of the recesses 3 adjacent to the loaves. In a wide range of stresses developed on the contact of the tyre with the ground during normal running, a large part, if not the whole, of the central zone 10 of the measuring element 1 glides over the ground. It has been found that this occurs even with free rolling (no torque) at low speed, including on grounds with strong adherence. This phenomenon of gliding of the central zone occurs at least during a part of each passage of the measuring element in the contact

area with the ground. The guarantee that said phenomenon of gliding will occur in the measuring element 1 makes it possible to measure the friction potential with the ground. In the remainder of the tread, on the other hand, only small parts glide over the ground, and these possibly gliding parts are far too small to provide an exploitable measurement for arriving at the friction potential.

It has been noticed that there exists in the centre of a tread block, that is to say at a certain distance from the edges 14, an excellent correlation between the forces directed tangentially, that is to say those providing all the accelerations of the vehicles, including guiding it, and occurring at the contact surface and the parallel forces which are able to be measured more in the interior, beyond the limit of the wear part of the tread.

According to a first embodiment, a thin strip relieves of stress the material situated radially beneath the surface of the central zone compared with the adjacent material situated beneath the encircling zone. Preferably, the thickness of said thin strip comes to approximately 0.3 mm to 2 mm. In some cases, said thin strip is at least partially inclined.

However, the invention relates per se to a tyre whose tread comprises at least one measuring element 1 whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a central zone 10 surrounded by an encircling zone 11, a thin strip relieving of stress the material situated radially beneath the surface of the central zone compared with the adjacent material situated beneath the encircling zone, a sensor 12 being arranged opposite said central zone, said sensor

being sensitive to at least one tangential force exerted at the surface of said central zone.

The relief of stress provided by the thin strip 13 makes it possible to carry out the measurement envisaged in a very acceptable manner, and it is thought that this is because said central zone offers less resistance to a force directed perpendicular to the surface of the tread than the resistance to a force directed perpendicular to the surface of the tread offered by the encircling zone. This makes it possible to prevent the occurrence of ground contact pressures which are too high to permit gliding of the central zone. Hence the general presentation of the invention given in the preamble above.

An advantage of the invention is to be able in this way to comprehend the available adherence margin up to total wear of the tyre, by means of a measurement of the friction potential made as indicated.

What is set out here is all the more usable for a tread devoid of pattern.

The tyre adapted in this way will make it possible to estimate the "adherence potential", a notion defined above and used mainly in conjunction with the tread as a whole. The tyre adapted in this way may also make it possible to estimate the "friction potential", a notion also defined above.

With one or more appropriate sensors 12, sensibly arranged, it is possible to obtain said measurements during the whole service life of the tyre. It is naturally desirable that the part of the tread of the tyre specific to the measurement is as small as possible, or more fundamentally

that said part does not detract from the performance of the tyre. It may be beneficial, therefore, to limit it to one or a small number of rubber loaves. The desired information may be obtained by making a single measurement per revolution of the tyre. In an advantageous manner, as shown in Figure 10, the tyre comprises sufficient measuring elements to ensure that there is always at least one of them in the contact area 20 with the ground. As for the vehicle, it is thought that it is superfluous that all its tyres should be covered by such measurements, one tyre per side may be sufficient.

Other embodiments of the invention may be envisaged. It is possible to mould in the central zone a plurality of cutouts in the form of wells. In certain cases, said cutouts in the form of wells are at least partially inclined.

However, the invention also relates per se to a tyre whose tread comprises at least one measuring element 1 whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a central zone 10 surrounded by an encircling zone 11, a plurality of cutouts being moulded into the central zone, a sensor 12 being disposed opposite said central zone, said sensor being sensitive to at least one tangential force exerted at the surface of said central zone.

This is illustrated in Figure 4. The presence of said cutouts makes it possible to carry out the measurement envisaged in a very acceptable manner, and it is thought that this is because said central zone offers less resistance to a force directed perpendicular to the surface of the tread than the resistance to a force directed

perpendicular to the surface of the tread offered by the encircling zone.

In a third embodiment, the Young's modulus of the material situated beneath the central zone is smaller than the Young's modulus of the adjacent material situated beneath the encircling zone. However, the invention relates per se to a tyre whose tread comprises at least one measuring element 1 whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a central zone 10 surrounded by an encircling zone 11, the Young's modulus of the material situated beneath the central zone being smaller than the Young's modulus of the adjacent material situated beneath the encircling zone, a sensor 12 being arranged opposite said central zone, said sensor being sensitive to at least one tangential force exerted at the surface of said central zone.

This is illustrated in Figure 5. The use of different materials makes it possible to carry out the measurement envisaged in a very acceptable manner, and it is thought that this is because said central zone offers less resistance to a force directed perpendicular to the surface of the tread than the resistance to a force directed perpendicular to the surface of the tread offered by the encircling zone.

The variants set out above may be advantageously combined. It is thus possible to maintain, during the whole service life of the tyre, a vertical contact pressure between the central zone of a measuring element and the ground which is sufficient to guarantee good accuracy of the measurement of the adherence potentials.

It is therefore possible to combine two or more than two of the concepts set out above, the relief of stress by a thin strip closed on itself being a first concept, the moulding of a plurality of cutouts being a second concept, and the use of materials having a different Young's modulus being a third concept. Figure 6 illustrates a combination of the first and third embodiments of a measuring element. Let us note that it is possible to envisage that the central zone of the measuring element is in this case constructed of a material with a Young's modulus greater than the Young's modulus of the material of which the encircling element is constructed. The materials of the latter may be adjusted in one direction or in another in order to promote to a greater or lesser extent the resistance to wear and the tendency to glide.

Figure 7 illustrates a combination of the first and second embodiments of a measuring element. It would naturally be possible to combine the characteristics of the three embodiments presented.

Figures 8 and 9 illustrate two variants of the first embodiment of an element, in which rubber bridges 5 connect locally the rubber beneath the central zone to the rubber beneath the encircling zone.

As a comment of general import, let us state that it is advantageous if the surface area of the central zone is at least substantially equivalent to the surface area of the encircling zone.

According to another aspect of the invention, illustrated in Figure 11, the tyre may present the following characteristics. L_r being the length of the measuring

element 1 in the preferred rolling direction shown by the arrow F, L_g being the length of the measuring element the direction perpendicular to the preferred rolling direction, L_1 being the length of the central zone 10 in the preferred rolling direction, L_2 being the length of the central zone 10 in the direction perpendicular to the preferred rolling direction, d_r being the minimum length measurable on the encircling zone 11 in the preferred rolling direction, d_g being the minimum length measurable on the encircling zone 11 in the direction perpendicular to the preferred rolling direction, the following relations are obeyed: $dr > Lr/10$, $dg > Lg/10$, $Lr/5 < L1 < 4Lr/5$ and $Lg/5 < L2 < 4Lg/5$.

Finally, Figures 12 to 14 show the numerous variants of shape (which are in fact infinite) which can be given to the central zone and to the encircling zone. Preferably, however, the following rule will be obeyed: the centre of mass of the measuring element 1 is in the central zone 10.

It was seen in the preamble that the invention proposes a method of detecting an adherence characteristics of the tread with the ground.

Based on a pre-established relation for linking the friction potential and the adherence potential of the tyre, on the one hand, and a procedure for regular recalibration using, for example, the property according to which the maximum adherence potential of the tyre to all the roadway conditions combined evolves only slightly, it is possible to deduce the value of the adherence potential of the tyre from the value of the shear stress exerted on the central zone of a measuring element or of any signal representative of said shear stress. Said recalibration procedure is necessary since the pressure beneath the central zone of a

measuring element may evolve during the use of the tyre, for example as a function of the wear on the tyre, for identical conditions of load on the tyre and of inflation pressure, and said evolution of the pressure introduces a variable which modifies the relation between the shear stress exerted on the central zone of a measuring element and the adherence potential of the tyre.

If the central zone of a measuring element is moreover equipped with a measurement of the vertical stress at the same point, it is possible to calculate the coefficient of friction between the central zone of a measuring element and the ground by calculating the ratio between the shear stress and the vertical stress. In this case, it is perhaps not necessary to perform a regular recalibration in order to evaluate the adherence potential of the tyre.

Consequently, in an advantageous variant of the proposed method of detection, the stages aimed at detecting a variation in said first signal and at producing an estimate of the adherence potential in said contact surface of the tyre comprise the following operations:

a) producing a second signal, representative of a vertical force in said contact surface of said central zone;
b) producing from the first and second signals a third signal, representative of the ratio between the tangential force and the vertical force;
c) detecting a variation of said third signal characteristic of a loss of adherence;
d) producing an estimate of the friction potential in said contact surface of the central zone; and
e) based on the friction potential, producing an estimate of the adherence potential of said tread.

It is possible to envisage carrying out measurements in the part of the tread external to what is called here "measuring element", that is to say in the part of the tread whose properties owe nothing to the concern to carry out measurements. The method proposed by the invention therefore comprises in addition the following stages:

a) disposing a sensor opposite a zone of the contact surface of the tread which is external to the measuring element or elements, said sensor being sensitive to at least one parameter reflecting a tangential force exerted at the surface of said external zone;
b) producing a first functional tread signal, representative of a tangential force in a zone of the contact surface of the tread which is external to the measuring element or elements;
c) producing a second functional tread signal, representative of a vertical force in a zone of the contact surface of the tread which is external to the measuring element or elements;
d) producing an indication characteristic of the tangential force applied to the tyre, based on the integration of said first functional tread signal, between the moments of the start and the end of contact with the ground of said external zone, and over the whole width of the tyre;
e) producing an indication characteristic of the vertical force applied to the tyre, based on the integration of said second functional tread signal, between the moments of the start and the end of contact with the ground of said external zone, and over the whole width of the tyre;
f) determining the "available adherence margin" by the difference between the adherence potential of the tread and the ratio between said tangential force and vertical force applied to the tread.

Let us pass to another aspect of the invention, interesting in itself. It is proposed to estimate the "available adherence margin" without carrying out a measurement or an estimate of the vertical force actually applied to the tyre. For this, the invention proposes a method for detecting a characteristic of adherence between a wheel possessing a deformable tread and a rolling ground, comprising the following stages:

a) providing in the tread at least one measuring element whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a central zone surrounded by an encircling zone, said central zone being arranged to glide over the ground at a level of stresses parallel with the surface of the ground which is substantially weaker than the level of stresses parallel with the surface of the ground beyond which the encircling zone glides over the ground;

b) disposing a sensor opposite said central zone, said sensor being sensitive to at least one parameter reflecting a tangential force exerted at the surface of said central zone;

c) producing a first signal representative of a tangential force in said central zone;

d) detecting on said first signal the moment of entry into the contact area of said central zone;

e) detecting on said first signal the moment at which the first signal undergoes a variation characteristic of a loss of adherence; and

f) producing an indication characteristic of an available adherence margin based on a function of the first signal between the moment of detection of entry into the contact area and the moment of detection of said characteristic variation.

Said function of the first signal is advantageously the ratio between the mean value of the first derivative of said signal plotted over time and the value of the signal at the point characteristic of a loss of adherence. As a variant, said function of the first signal is the time interval separating said detections.

Finally, as a variant, the invention proposes a method of detecting a characteristic of adherence between a wheel possessing a deformable tread and a rolling ground, comprising the following stages:

a) providing in the tread at least one measuring element whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a central zone surrounded by an encircling zone, said central zone being arranged to glide over the ground at a level of stresses parallel with the surface of the ground which is substantially weaker than the level of stresses parallel with the surface of the ground beyond which the encircling zone glides over the ground;
b) disposing a sensor opposite said central zone, said sensor being sensitive to at least one parameter reflecting a tangential force exerted at the surface of said central zone;
c) disposing a sensor opposite a zone of the contact surface of the tread which is external to the measuring element or elements, said sensor being sensitive to at least one parameter reflecting a tangential force exerted at the surface of said external zone;
d) producing a first signal representative of a tangential force in said central zone;
e) producing a second signal representative of a tangential force in said external zone;

f) producing an indication characteristic of an available adherence margin based on a comparison of said first and second signals.

The adherence potential of the tyre to the roadway determines directly the maximum level of the guiding, braking and driving forces which can be transmitted to the vehicle. It is a critical element in the mobility and road holding properties of vehicles.

Statistical studies carried out in several countries show that there is an undeniable link between this adherence potential and the risk of accidents on a wet roadway: the weaker the level of the adherence potential to a wet roadway is, the greater is the risk of an accident. The safety of road-users therefore depends to a large extent on the adherence potential.

An important safety factor here is the ability to estimate the level of the adherence potential of the tyre as soon as possible before the adherence limit is reached, since the possibility of avoiding an accident in the event of insufficient adherence will be that much greater if the actions to adapt the rolling conditions of the vehicle are taken at an early stage.

The design principle of the tyre presented here represents an important advantage from this point of view. It makes it possible, in fact, to estimate the level of the adherence potential even when the tyre is rolling freely, which amounts to saying that it is possible to determine said potential in all rolling conditions of the vehicle, from the rolling situation in a straight line at constant speed up to situations of maximum braking and acceleration, or of

turns close to the adherence limit. The available adherence potential can thus be estimated permanently.

Based on the measurements described, it is also possible to know the part of the adherence potential which is actually utilised.

The following table illustrates applications permitted by a knowledge of this information.

	RECIPIENT OF THE INFORMATION		
INFORMATION RECORDED	DRIVER	VEHICLE	OTHER USERS AND ROAD MANAGERS
Adherence potential	• Inform of the variations in limit of adherence potential • Compare the momentary potential with a statistical population of the adherence levels and inform of the position of this momentary potential compared with this population (high, average, weak, very weak level)	• Adapt the control strategy of active systems (anti-locking, antiskid, path monitoring) • Assist the driver, correct actions when the latter seem unsuitable or when corrective action seems necessary given the expected response of the vehicle	• Inform other users of the available adherence level at all points of the network (in combination with a position tracking system) • Supply the bodies respons-ible for the upkeep of the network with real time data permitting optimum management of the upkeep
Available adherence margin	Inform the driver of the level of use of the potential and alert him to the approach of the adherence limit00	Regulate active systems (antilocking, antiskid, path monitoring)	Alert managers of the road networks to areas where the adherence limit is most often approached

Based solely on a knowledge of the available adherence potential, or of information directly related to the adherence potential, it is possible:

- to inform the driver of the vehicle:
  - → when variations in the adherence level occur: for example, if the potential declines beyond a certain variation limit, an alert may be supplied to the driver in audible or visual form to encourage him to adapt his driving and to increase his vigilance;
  - → of the relative adherence level which is available to him at a given moment compared with a statistical base of the adherence limits encountered: the information sampled continuously, when the vehicle is rolling, may supply a data base implanted in a computer system connected to the vehicle or external to the vehicle (centralised data base with which the vehicle would communicate); in addition, said information may be compared with the statistical population already stored in the data base in order to determine the percentile of the population to which it corresponds; said result may be converted into a single item of information supplied to the driver (for example, by the indication of an agreed level describing the available adherence: high, average, weak, very weak);

- to act on the vehicle:
  - → by adapting the control strategies of systems of the vehicle such as the wheel antilocking, antiskid and active path monitoring systems: said systems could possess strategies differing according to the adherence level and predefined by construction;

depending on the momentary adherence level, the most suitable control strategy could be implemented;

→ by permitting the determination of the optimal actions to be applied to a component of the vehicle: numerical simulations in real time can now be carried out in the vehicles; with a knowledge of the adherence level, it is possible to establish the action to be applied to a component (for example brake) in order that the response is optimal; it is also possible to predict by simulation what will be the response of the vehicle to the actions performed by the driver and to consequently correct his actions or to assist him should the actions appear unsuitable;

- to inform other road users and bodies responsible for the upkeep of the road network, by communicating said information to central data bases; the current means of communication and location of the mobiles (GPS system for example) make it possible to assign to each item of information concerning the adherence potential supplied by a vehicle, the precise location of the corresponding portion of road, and to transmit this information to a centralised system; on the basis of this information, it is possible:

→ to inform other users of the road, and their vehicles, of the level available at a given point even before they have reached said point, which makes it possible to anticipate to an even greater extent any corrective measures required in terms of the controls of the vehicles;

→ to supply the managers of the road network with accurate statistical information in real time on the adherence level, thus rendering superfluous the

regular operations to measure the adherence which are carried out in certain countries in order to monitor their road network,

If this information on the available adherence potential is complemented with the information on the adherence level actually used, it is possible in addition:

- to inform the driver of the rate of use of said available potential and to alert him to the approach of the adherence limit;
- to regulate systems of the vehicle (wheel antilocking and antiskid systems, for example) directly from the difference between the available potential and the potential used;
- to supply the persons responsible for managing the road network with statistical information enabling them to detect the points of the network where the adherence limit is most often approached and where the risk of an accident may consequently be considerable, even before this risk is highlighted by accident statistics.

It is possible, for example, to carry out a measurement as set out in the patent DE 3937966 A1. It has been seen that a magnetic element may be supplemented in the central zone with a measuring element, at a place such that said element undergoes a relative displacement with respect to sensors with Hall effect placed in the tread when said measuring element is subjected to a tangential force or to a normal force. The sensors with Hall effect are disposed so as to measure the minimum displacement of the magnetic element under the effect of a tangential force applied to the surface of a measuring element, or even to measure in addition its displacement, in a clear manner.

As a variant, it would also be possible to perform a measurement as taught by the US patents 5 864 056 or 5 502 433.

The signals thus measured are sent to a calculating unit which determines the adherence potential and the available adherence margin according to one of the proposed methods. It is noted that the current technology permits the transmission, preferably the remote transmission, of signals from one or more measuring units implanted in the tread and the vehicle itself, and that it is not the aim of the present invention to deal with this aspect, which is relatively independent of the measuring aspects which are dealt with here.

These calculated items of information are themselves addressed, for example, to a device enabling the driver to be informed, or else are sent, for example by radio means, to a system external to the vehicle allowing centralisation of the information relating to the adherence potential with the ground and designed to notify all road users, or else again are used to regulate systems or components of the vehicle to which the tyre is fitted.

Claims

1. Tyre whose tread comprises at least one measuring element (1) whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a central zone (10) surrounded by an encircling zone (11), said central zone having a resistance to a force directed perpendicular to the surface of the tread which is less than the resistance to a force directed perpendicular to the surface of the tread offered by the encircling zone, a sensor (12) being disposed opposite said central zone, said sensor being sensitive to at least one tangential force exerted at the surface of said central zone.

2. Tyre according to claim 1, in which a thin strip relieves of stress the material situated radially beneath the surface of the central zone compared with the adjacent material situated beneath the encircling zone.

3. Tyre according to one of claims 1 or 2, in which a plurality of cutouts in the shape of wells are moulded into the central zone.

4. Tyre according to one of claims 1 to 3, in which the Young's modulus of the material situated beneath the central zone is smaller than the Young's modulus of the adjacent material situated beneath the encircling zone.

5. Tyre whose tread comprises at least one measuring element (1) whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the

tread, having a central zone (10) surrounded by an encircling zone (11), a thin strip relieving of stress the material situated radially beneath the surface of the central zone compared with the adjacent material situated beneath the encircling zone, a sensor (12) being arranged opposite said central zone, said sensor being sensitive to at least one tangential force exerted at the surface of said central zone.

6. Tyre according to one of claims 2 or 5, in which the thickness of said thin strip comes to approximately 0.3 mm to 2 mm.

7. Tyre according to one of claims 2 or 5 or 6, in which said thin strip is at least partially inclined.

8. Tyre whose tread comprises at least one measuring element (1) whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a central zone (10) surrounded by an encircling zone (11), a plurality of cutouts being moulded into the central zone, a sensor (12) being disposed opposite said central zone, said sensor being sensitive to at least one tangential force exerted at the surface of said central zone.

9. Tyre according to claim 3 or 8, in which said cutouts in the shape of wells are at least partially inclined.

10. Tyre whose tread comprises at least one measuring element (1) whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a central zone (10) surrounded by an

encircling zone (11), the Young's modulus of the material situated beneath the central zone being smaller than the Young's modulus of the adjacent material situated beneath the encircling zone, a sensor (12) being disposed opposite said central zone, said sensor being sensitive to at least one tangential force exerted at the surface of said central zone.

11. Tyre according to one of claims 1 to 10, in which the surface area of the central zone is at least substantially equivalent to the surface area of the encircling zone.

12. Tyre according to one of claims 1 to 10 in which, L_r being the length of the measuring element (1) in the preferred rolling direction, L_g being the length of the measuring element in the direction perpendicular to the preferred rolling direction, L_1 being the length of the central zone (10) in the preferred rolling direction, L_2 being the length of the central zone (10) in the direction perpendicular to the preferred rolling direction, d_r being the minimum length measurable on the encircling zone (11) in the preferred rolling direction, d_g being the minimum length measurable on the encircling zone (11) in the direction perpendicular to the preferred rolling direction, the following relations are obeyed: $dr > Lr/10$, $dg > Lg/10$, $Lr/5 < L1 < 4Lr/5$ and $Lg/5 < L2 < 4Lg/5$.

13. Tyre according to one of claims 1 to 10, in which the centre of mass of the measuring element (1) is in the central zone (10).

14. Tyre according to one of claims 1 to 13, comprising sufficient measuring elements to ensure that there is

always at least one of them in the contact zone with the ground.

15. Tyre according to one of claims 1 to 14, in which the sensor (12) is embedded in the wall of said tyre.

16. Tyre according to claim 15, in which the sensor (12) is arranged outside the part of the tread intended to become worn during the use of said tyre.

17. Tyre according to one of claims 1 to 16, in which the sensor (12) comprises a device or devices with Hall effect.

18. Method of detecting a characteristic of adherence between a wheel possessing a deformable tread and a rolling ground, comprising the following stages:
   a) providing in the tread at least one measuring element whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a central zone surrounded by an encircling zone, said central zone being arranged to glide over the ground with a level of stresses parallel to the surface of the ground which is substantially weaker than the level of stresses parallel to the surface of the ground beyond which the encircling zone glides over the ground;
   b) arranging a sensor opposite said central zone, said sensor being sensitive to at least one parameter reflecting a tangential force exerted at the surface of said central zone;

c) producing a first signal representative of a tangential force in said contact surface of the central zone;

d) detecting a variation in said first signal which is characteristic of a loss of adherence;

e) producing an estimate of the friction potential in said contact surface of the central zone;

f) producing an estimate of the adherence potential of the tread.

19. Method of detection according to claim 18 in which the stages aimed at detecting a variation in said first signal and at producing an estimate of the adherence potential of the tread comprise the following operations:

a) producing a second signal, representative of a vertical force in said contact surface of said central zone;

b) producing from the first and second signals a third signal, representative of the ratio between the tangential force and the vertical force;

c) detecting a variation of said third signal characteristic of a loss of adherence;

d) producing an estimate of the friction potential in said contact surface of the central zone; and

e) based on the friction potential, producing an estimate of the adherence potential of said tread.

20. Method according to one of claims 18 or 19, comprising in addition the following stages:

a) disposing a sensor opposite a zone of the contact surface of the tread which is external to the measuring element or elements. said sensor being sensitive to at least one parameter reflecting a

tangential force exerted at the surface of said external zone;

b) producing a first functional tread signal, representative of a tangential force in a zone of the contact surface of the tread which is external to the measuring element or elements;

c) producing a second functional tread signal, representative of a vertical force in a zone of the contact surface of the tread which is external to the measuring element or elements;

d) producing an indication characteristic of the tangential force applied to the tyre, based on the integration of said first functional tread signal, between the moments of the start and the end of contact with the ground of said external zone, and over the whole width of the tyre;

e) producing an indication characteristic of the vertical force applied to the tyre, based on the integration of said second functional tread signal, between the moments of the start and the end of contact with the ground of said external zone, and over the whole width of the tyre;

f) determining the "available adherence margin" by the difference between the adherence potential of the tread and the ratio between said tangential force and vertical force applied to the tread.

21. Method of detecting a characteristic of adherence between a wheel possessing a deformable tread and a rolling ground, comprising the following stages:

a) providing in the tread at least one measuring element whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a central zone surrounded by

an encircling zone, said central zone being arranged to glide over the ground at a level of stresses parallel with the surface of the ground which is substantially weaker than the level of stresses parallel with the surface of the ground beyond which the encircling zone glides over the ground,

b) disposing a sensor opposite said central zone, said sensor being sensitive to at least one parameter reflecting a tangential force exerted at the surface of said central zone,

c) producing a first signal representative of a tangential force in said central zone,

d) detecting on said first signal the moment of entry into the contact area of said central zone,

e) detecting on said first signal the moment at which the first signal undergoes a variation characteristic of a loss of adherence and

f) producing an indication characteristic of an available adherence margin based on a function of the first signal between the moment of detection of entry into the contact area and the moment of detection of said characteristic variation.

22. Method of detection according to claim 21 in which said function of the first signal is the ratio between the mean value of the first derivative of said signal plotted against time and the value of the signal at the point characteristic of a loss of adherence.

23. Method of detection according to claim 21 in which said function of the first signal is the time interval separating said detections.

24. Method of detecting a characteristic of adherence between a wheel possessing a deformable tread and a rolling ground, comprising the following stages:

a) providing in the tread at least one measuring element whose surface is intended to come into contact with the ground at each revolution of the tyre, said measuring element, viewed at the surface of the tread, having a central zone surrounded by an encircling zone, said central zone being arranged to glide over the ground at a level of stresses parallel with the surface of the ground which is substantially weaker than the level of stresses parallel with the surface of the ground beyond which the encircling zone glides over the ground,

b) disposing a sensor opposite said central zone, said sensor being sensitive to at least one parameter reflecting a tangential force exerted at the surface of said central zone,

c) disposing a sensor opposite a zone of the contact surface of the tread which is external to the measuring element or elements, said sensor being sensitive to at least one parameter reflecting a tangential force exerted at the surface of said external zone,

d) producing a first signal, representative of a tangential force in said central zone;

e) producing a second signal, representative of a tangential force in said external zone;

f) producing an indication characteristic of an available adherence margin based on a comparison of said first and second signals.

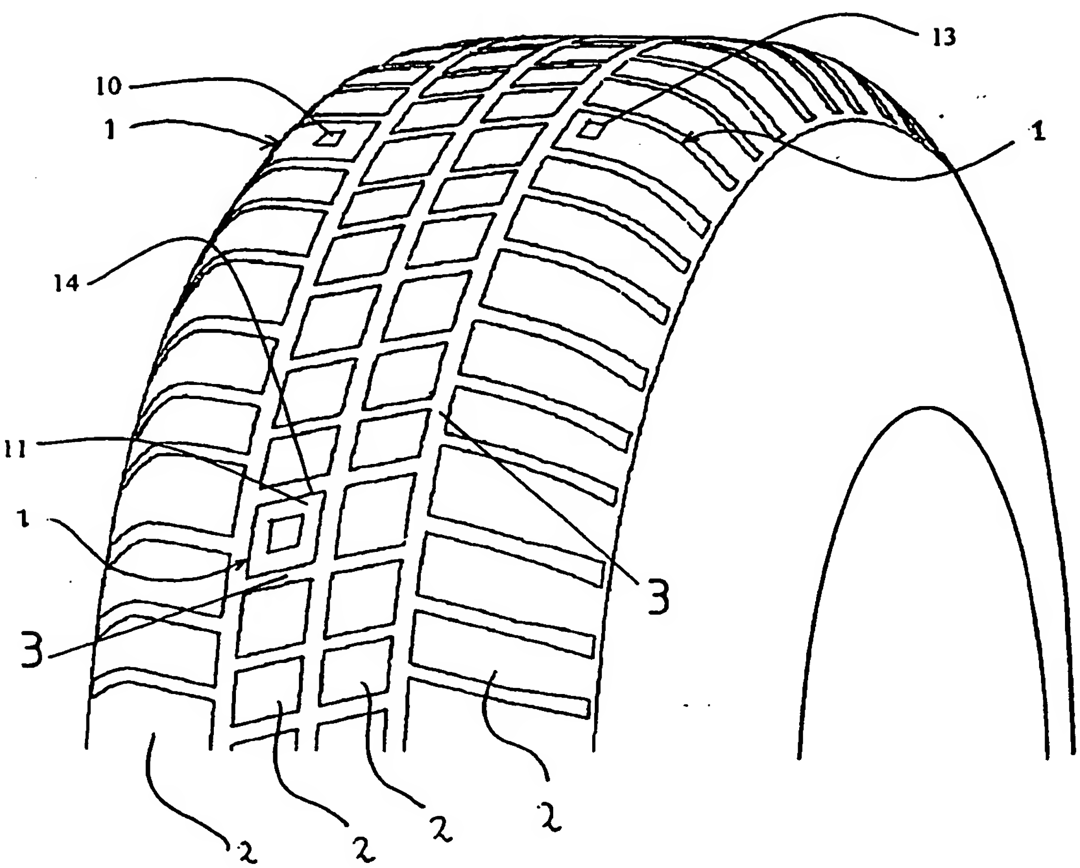

Fig 1

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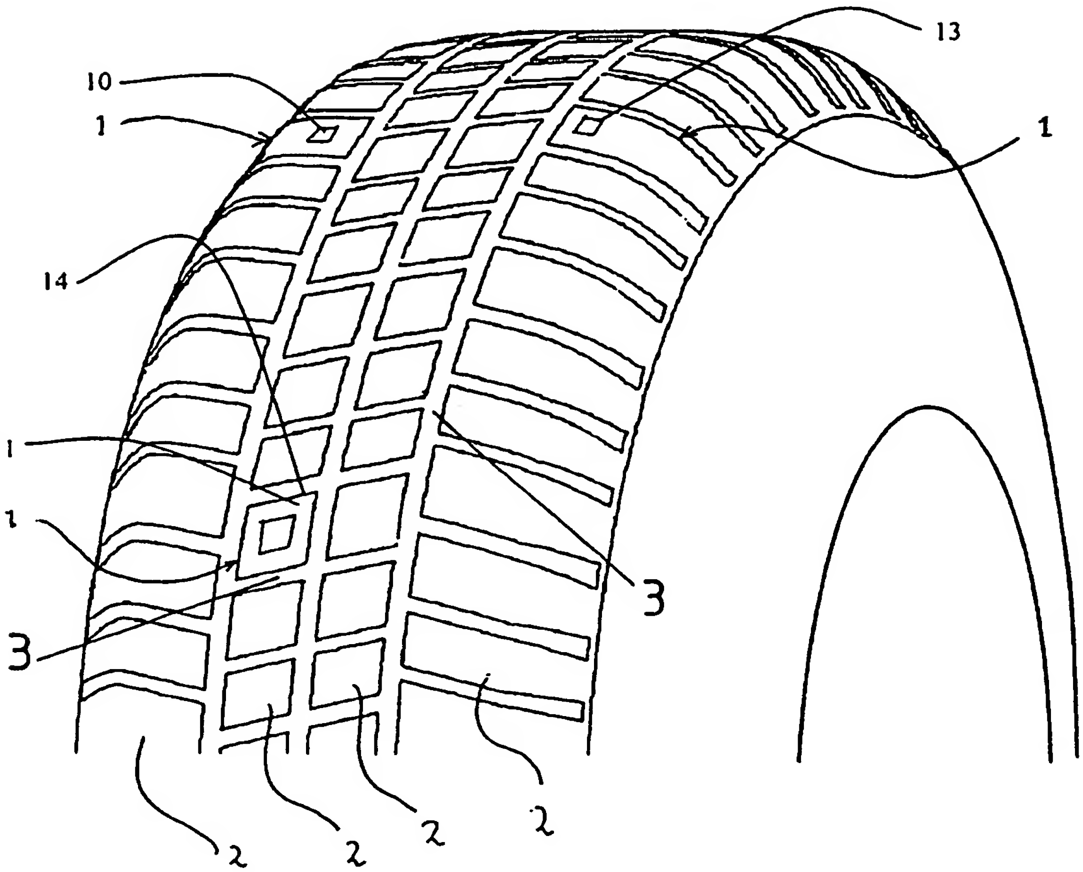

Fig 1

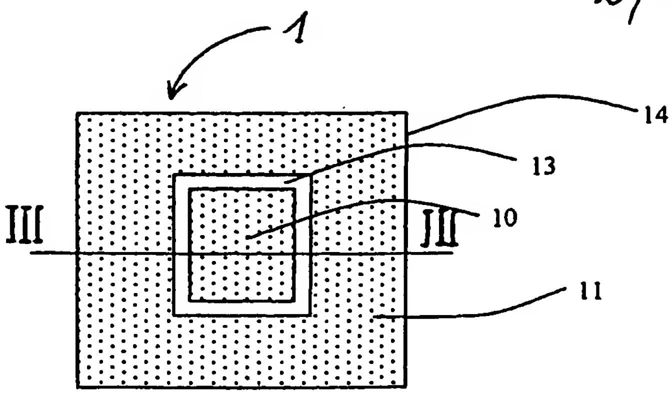

Fig. 2

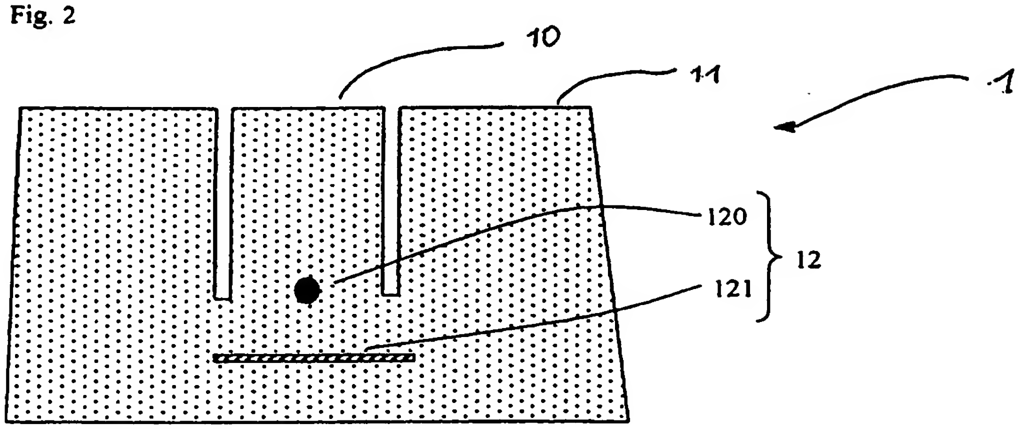

Fig. 3

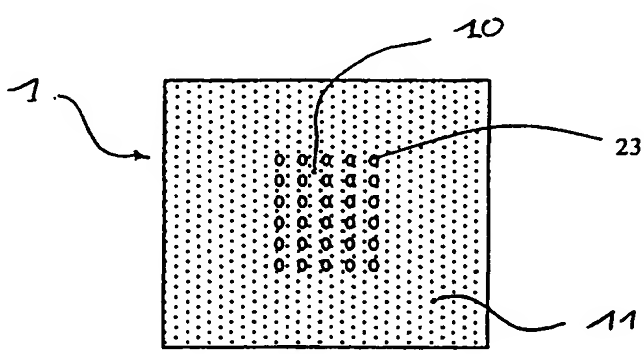

Fig. 4

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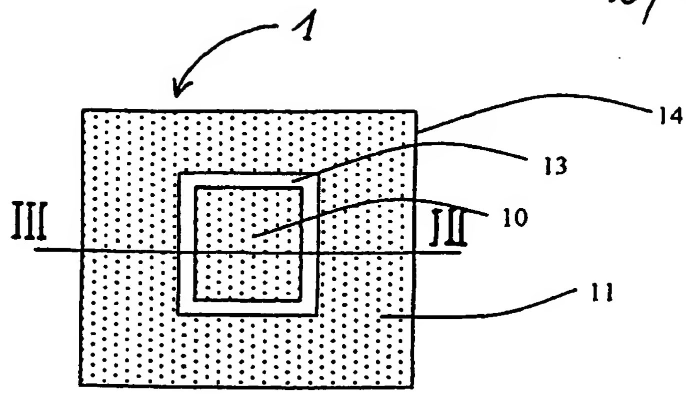

Fig. 2

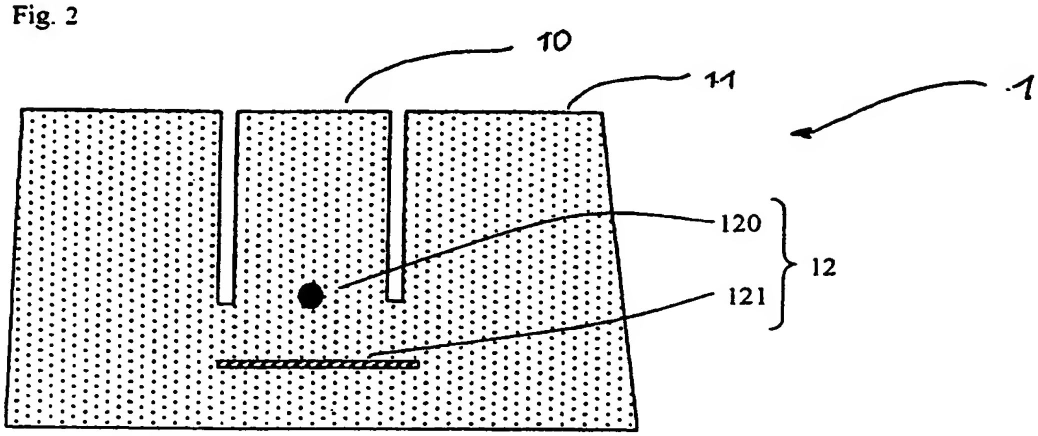

Fig. 3

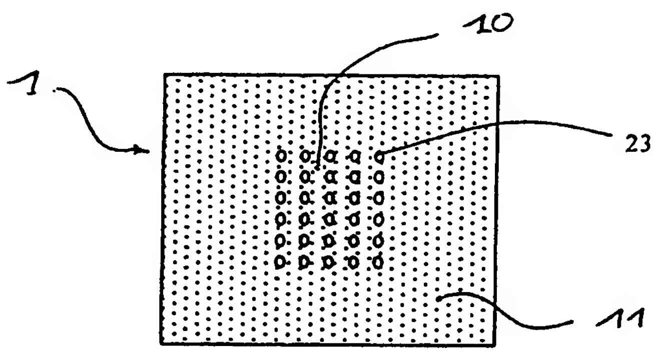

Fig. 4

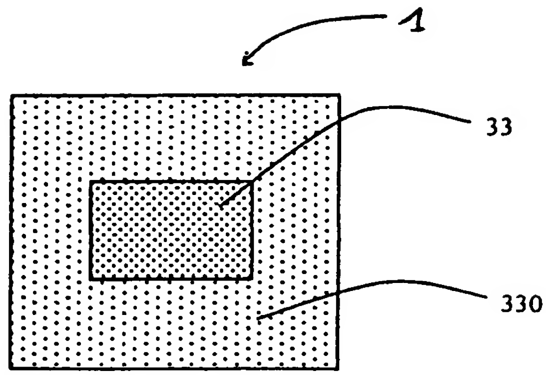

Fig. 5

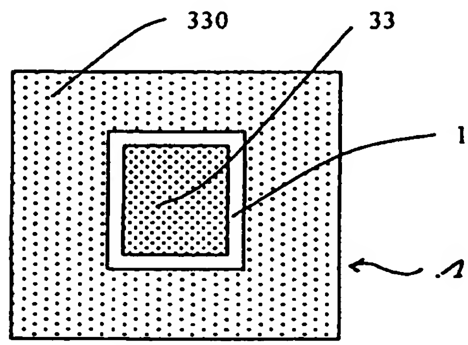

Fig. 6

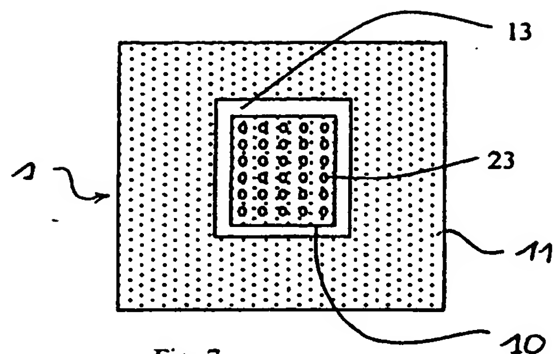

Fig. 7

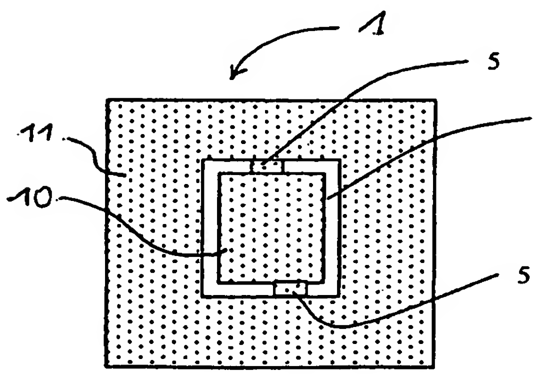

Fig. 8

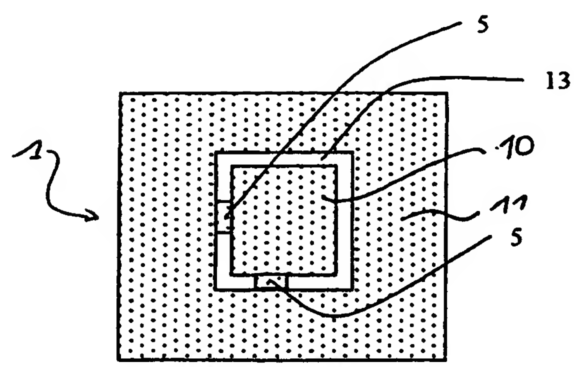

Fig. 9

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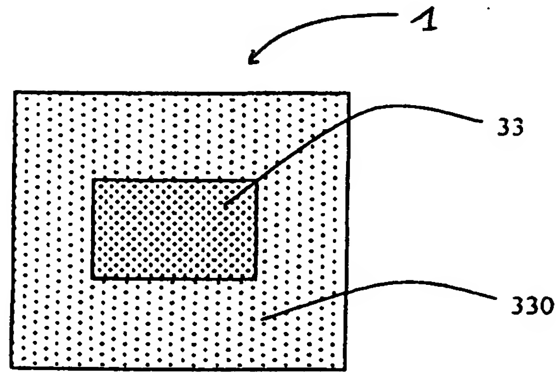


Fig. 5

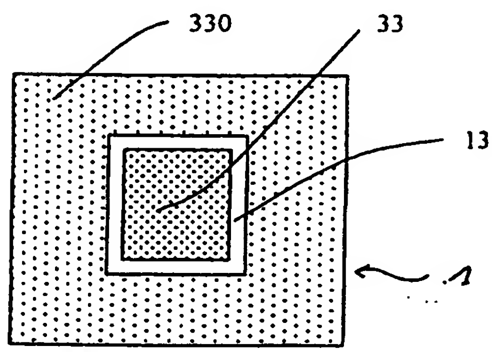


Fig. 6

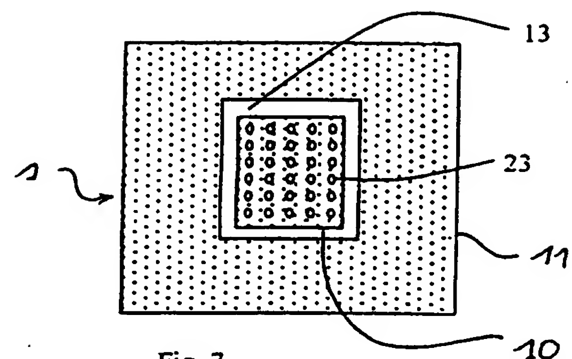


Fig. 7

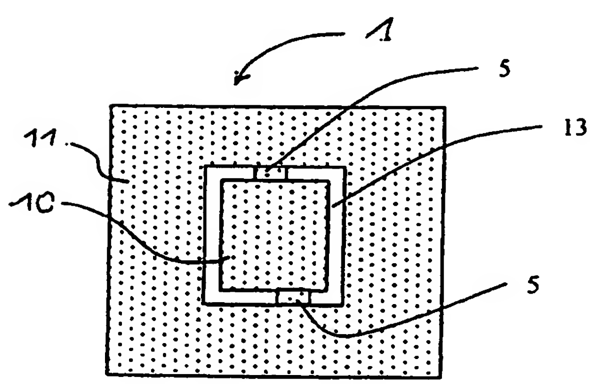


Fig. 8

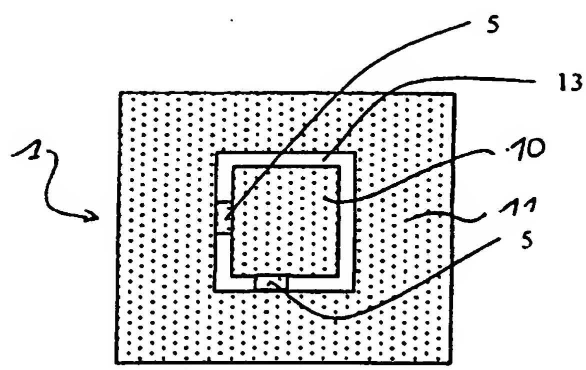


Fig. 9

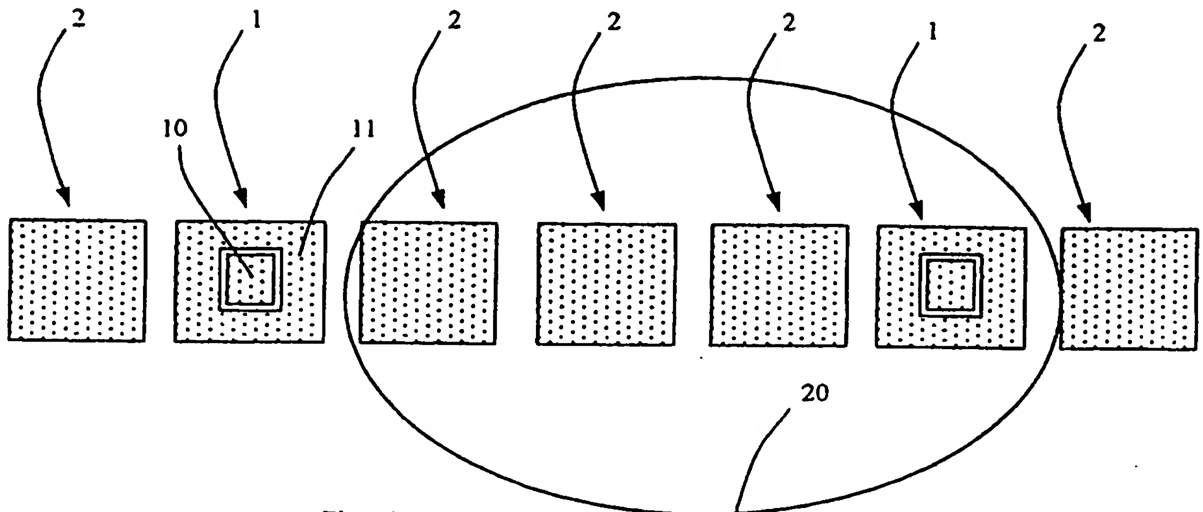


Fig. 10

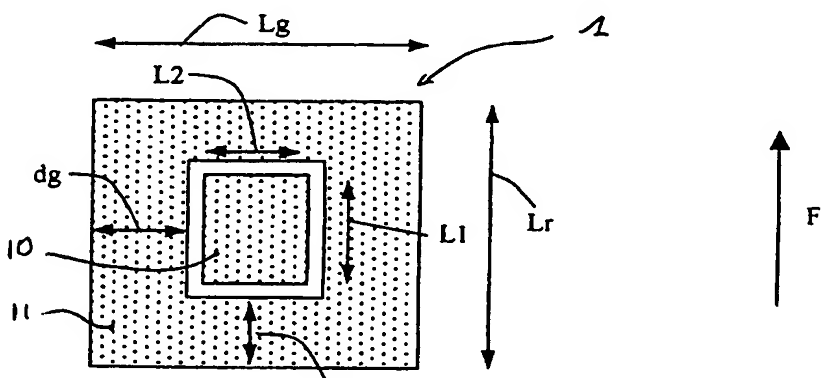
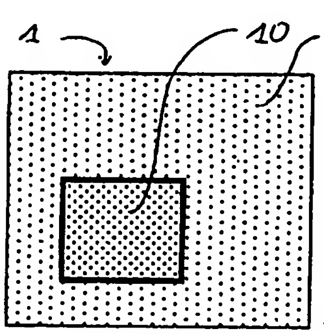
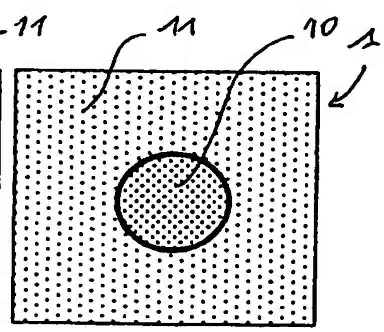


Fig. 11





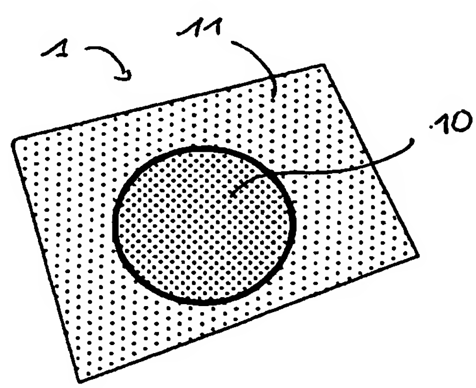


Fig. 12

Fig. 13

Fig. 14

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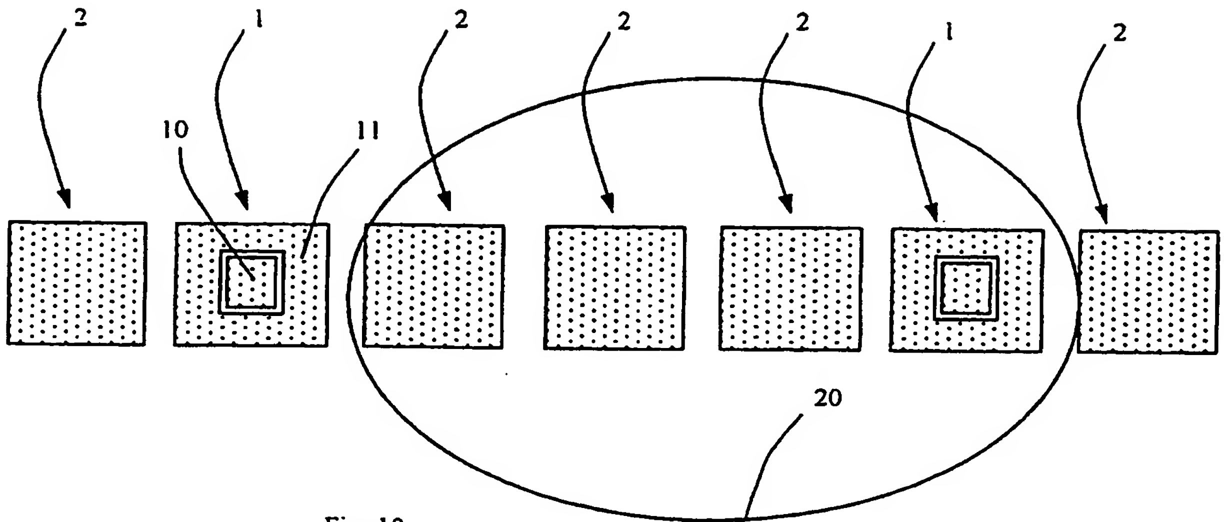


Fig. 10

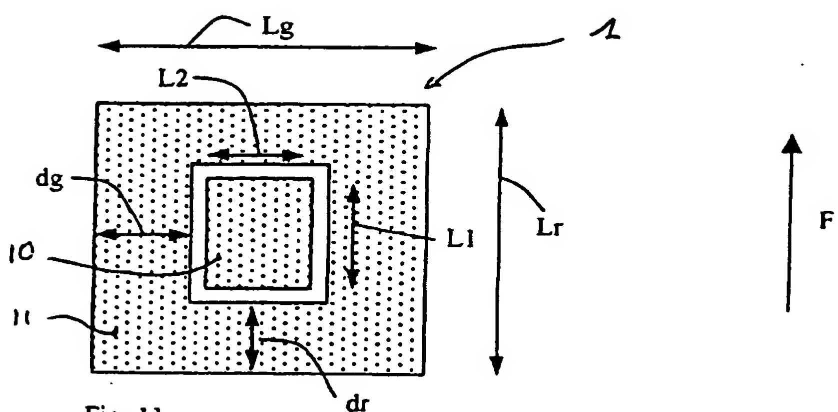


Fig. 11

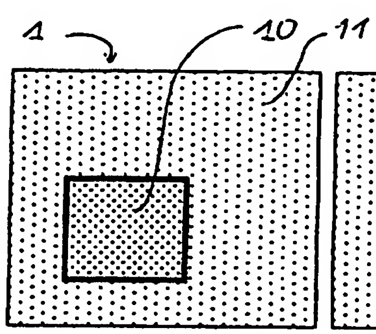


Fig. 12

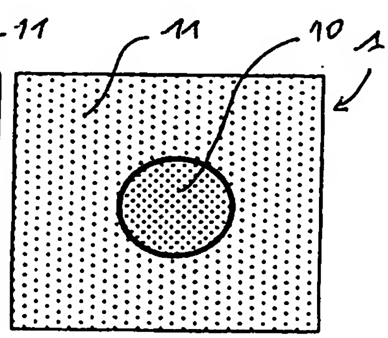
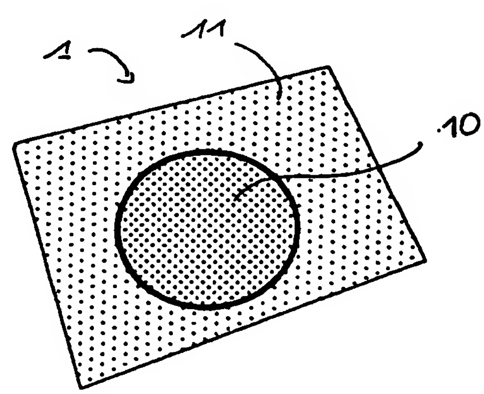


Fig. 13



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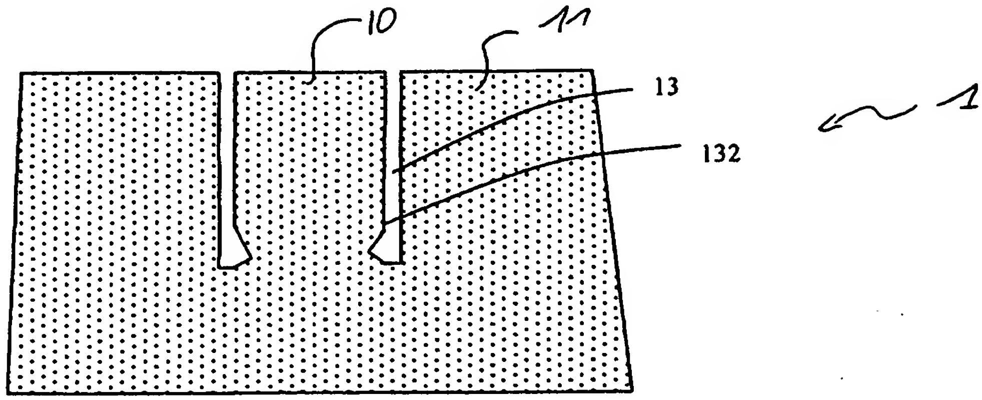
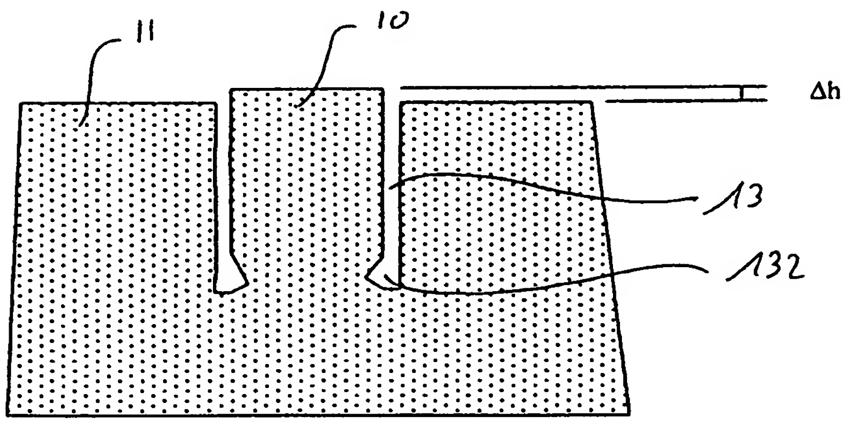


Fig. 15



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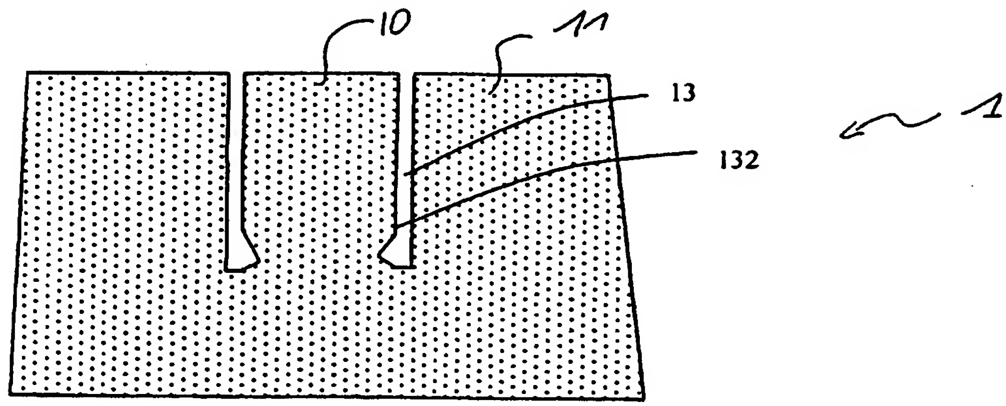

Fig. 15

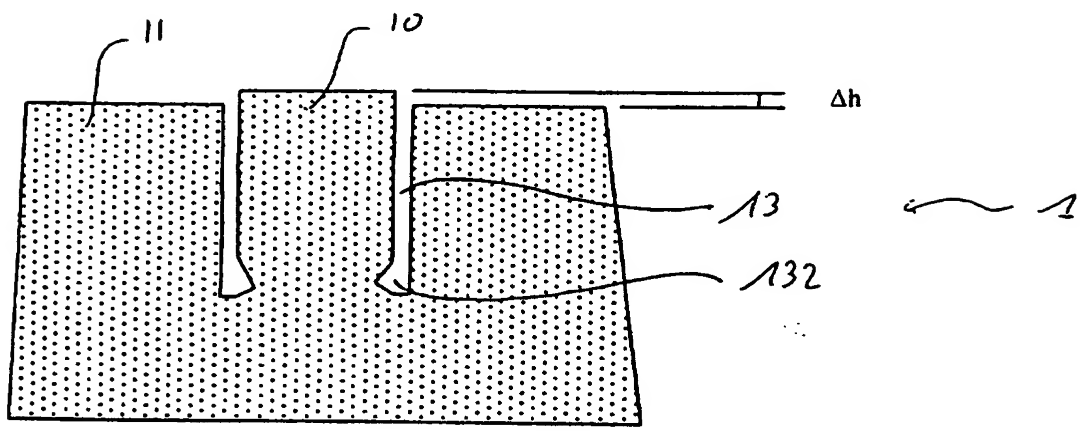

Fig. 16